Spec CAD-1172

Brookhaven National Laboratory		Spec. No.	CAD-1172
Brookhaven Science Associates		Issue Date:	15 Sept 2005
CAD Department		Rev. No.	-A
		Rev. Date:	22 Sept 2005

Title: **Specification for EBIS Superconducting Solenoid Magnet System**

QA Category: A-2

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Revision Record

Rev. No	Date	Page	Subject	ECN
A	22 Sept 2005	3, para 3.1.3.2	Radial Load Capacity 600N was 300N	

BROOKHAVEN NATIONAL LABORATORY
Brookhaven Science Associates, Inc.
Specification for EBIS Superconducting Solenoid Magnet System

1.0 Scope of Work

1.1 This specification outlines the requirements governing the design, construction, and performance of the EBIS Superconducting Solenoid Magnet System. The magnet is a 6 Tesla, 2 meter long horizontal solenoid with 204 mm warm bore.

2.0 Applicable Documents

2.1 The latest editions and revisions of the following documents form a part of this specification to the extent specified herein. The Seller shall notify BNL in writing of any requirements contained in this Specification which conflicts with the requirements of the various Industry Codes and Standards referenced herein. Exceptions must be approved in writing by BNL. Unless otherwise specified, the issue date or revision level shall be that in effect on the date of the invitation to quote.

ASME Section VIII Boiler and Pressure Vessel Code for Unfired Pressure Vessels
ASME Section IX Boiler and Pressure Vessel Code – Welding Qualifications
NEC National Electrical Code
NIST National Institute of Standards and Technology

3.0 Requirements

3.1 Design Requirements

3.1.1 Physical Size.

Inner diameter of the warm bore	204 mm
Total length of solenoid	2000 mm
Length of vacuum jacket*	less than 2300 mm

* The length of the cryostat should be minimized to allow the placement of elements outside of the cryostat as close to the vacuum vessel/cryostat as possible.

3.1.2 Magnet Bore. The accessible room temperature bore of the magnet shall be circular in cross-section with a minimum diameter of 204 mm to provide clearance for a standard 8” conflat type flange. This circular aperture shall be available throughout the length of the magnet under all operating conditions. A warm bore design that permits external positioning of the bore relative to the solenoidal field is an acceptable method for achieving field coaxial tolerance specified herein.

3.1.3 External Loads.

3.1.3.1 Axial Load Capacity. The magnet design shall be capable of withstanding an axial load from magnetic interaction with a steel flange attached to either side flange of vacuum chamber, but not both. The magnet shall safely and effectively resist this force while maintaining the liquid helium evaporation rates specified. Specifically, the design shall withstand the force generated by the interaction of the coil and a 300 mm diameter, 20 mm thick iron flange mounted on either end.

3.1.3.2 Radial Load Capacity. The solenoid shall designed for a maximum permissible radial force of 600 N.

3.1.4 Current Leads. The magnet shall be fitted with demountable current leads optimized for running the magnet in the persistent mode. The maximum safe ramp rate shall be determined during testing and programmed in the control system.

3.1.5 Magnet Pressure Vessels. The pressure/vacuum vessels shall be designed to meet the requirements of Section VIII of the ASME Boiler and Pressure Vessel Code. The pressure and vacuum vessels shall be designed to operate safely in the presence of all normal and potential thermal, structural, magnetic, and pressure loads. Pressure vessels shall be hydrostatically tested to 50% above the maximum allowable pressure rating. Certified copies of the hydrostatic pressure tests shall be provided.

3.1.6 Pressure Relief Devices. The cryogen vessels shall be protected from potential over-pressure conditions, including but not limited to, loss of vacuum, quench, and accidental over-pressurization from external sources. Devices used on cryogenic systems design for this service and shall be installed such that their proper functioning will not be affected by cold temperatures. The vacuum vessel shall have pressure relief devices to protect from cryogen vessel failure.

Pressure relief devices shall be installed so that they are readily accessible for inspection and/or repair. All connections and discharge lines shall be of sufficient cross-sectional area so as not to restrict the pressure relief device. All pressure relief devices shall discharge to a safe region in such a manner that the sudden escape of a contained gas will not endanger the environment or personnel in the vicinity of the equipment. All relief devices shall be certified by the manufacturer for the operating pressure. These devices shall be marked with all information required by the ASME Code. Relief devices shall be sized to prevent the pressure from exceeding 10% above the maximum allowable working pressure under potential worst case conditions.

3.1.6.1 Relief Valves. Adjustable relief valves shall be sealed to prevent tampering.

3.1.6.2 Burst Disks. When burst disks are used, the Seller shall supply two spare disk elements for each type. Disks devices shall be marked with manufacturer, model number, and pressure rating and shall be constructed of materials suitable for the possible operating temperatures.

3.1.7 Piping, Tubing, Fittings, and Valves. Piping, tubing, fittings, and valves shall be rated at or above the system maximum working pressure, and documentation of manufacturer's specifications shall be available during the system Detail Design/Safety Review.

3.1.8 Service Connections. All magnet service connections shall be located at least 200 mm inboard of the magnet ends. This includes electric power connections as well as cryogen connections. The helium fill shall be fitted with a ball valve at the inlet (note: transfer line designed with insertion tube must pass through O-ring seal and ball valve).

3.1.9 Magnet Stand. The magnet shall be designed to be secured to a magnet stand. BNL will provide a stand for the magnet which will enable accurate vertical and lateral adjustment of the magnet in the beam line. The stand/magnet interface will be mutually agreed upon after award of contract.

3.1.10 Installation Site. The magnet system must operate as specified and be capable of being serviced (e.g., filled) after being installed at the EBIS facility located in Bldg. 930. This building may experience temperatures of 5 to 35 C and a relative humidity of up to 95%.

3.1.11 Lifting Points. The magnet shall be equipped with suitable lifting points for safe handling and rigging into place.

3.1.12 Fiducial Markings for Specification of Magnetic Axis. The manufacturer shall provide fiducial lines on both ends of the cryostat indicating vertical and horizontal lines perpendicular to the magnetic axis of the solenoid at liquid helium temperatures to within 0.2mm.

3.1.13 Helium Transfer Line. A flexible 2.3 meter helium transfer line shall be provided with the magnet system for filling the magnet from a helium dewar. The dewar insertion tube shall be 0.375" diameter and 1.5 m long. The annular insulation vacuum volume in the flex hose shall be fitted with an evacuation valve for pumping down and a relief valve.

3.2 Performance Requirements

3.2.1 Field Specifications:

Magnet field	6 Tesla
Homogeneity over volume of 1500mm Z x 10mm dia	0.25%
Positional tolerance of the magnet field axis over the full length of the magnet	0.2 mm
Maximum deviation of radial position of the	

solenoid axis from the warm bore axis	0.5 mm
Decay rate of the magnet field in coils of solenoid operating in persistent mode with current leads removed	1 ppm/hour

3.2.2 Field Strength and Uniformity. The central field shall be uniform to better than 0.25% in a volume of 10 mm diameter by 1500 mm in length. This 'volume of uniformity' shall have a straightness, Br/Bz, of one part in 10,000. The field shall be symmetrical about the geometric Z center of the magnet where Z is the direction along the magnet bore (Z = 0 at the center). Appendix A shows examples of acceptable and unacceptable field plots. Gross bumps or depressions in the field shall be avoided.

3.2.3 Magnet Polarity. The magnet shall be capable of operating to full field and current in either polarity.

3.2.4 Operating Margin. The magnet system shall be capable of operating at 105% of the specified field without quenching.

3.3 Cryogenic Requirements

3.3.1 Unattended Operations. The magnet system shall be capable of safe and reliable operation in the persistent mode with its own self-contained liquid helium supply as specified below, with the exception of routine liquid nitrogen filling for LN2 cooled heat shields:

Period between refilling of liquid helium	35 days
Period between refilling of liquid nitrogen (i.e., for LN2 cooled heat shields)	10 days

3.3.2 Quench Protection. The design of the magnet must assure that the magnet will be safe from damage arising from a quench for any reason and under any condition.

3.3.3 Quench Recovery. The magnet shall fully recover from a quench to permit maximum field operation in eight hours or less following a quench.

3.3.4 Service Interval. The liquid helium evaporation rate shall not exceed 0.2 liquid helium liters per hour in the persistent mode at maximum field with leads removed. The evaporation rate with the current leads attached while in persistent mode at full field shall be less than 0.3 liquid helium liters per hour. Liquid helium will be filled from a dewar at slightly above atmospheric pressure. The amount of time required to perform routine helium filling shall be less than 2 hours, and the magnet shall be capable of continuous, unimpeded running during this servicing.

The liquid nitrogen evaporation rate for LN2 cooled heat shields shall not exceed 0.8 LN2 liters per hour. The amount of time required to perform routine liquid nitrogen filling shall be less than 4 hours.

3.3.5 Start-up Time. The start-up time of the unevacuated magnet from room temperature to full of liquid helium and ready to be energized shall be less than 2 days. The amount of liquid helium required to cool down and fill up shall be recorded during testing.

3.3.6 Helium Recovery. BNL prohibits the intentional release of helium gas to the environment; therefore provision must be made in the design for a common connection point of helium gas vents to a BNL supplied gas recovery system operating at a maximum of 1.15 atmospheres back pressure. Vent lines shall have standard end fittings for connection to external piping or tubing.

3.4 Power, Instrumentation, and Control Requirements

3.4.1 Power Supply. The power supply shall be controllable with a variable set point, adjustable ramp speed, and be designed to meet the field ramp, drift and set point criteria with an adequate safety margin. Elements of the power supply shall be off-the-shelf and readily available for replacement to the extent that is practical. In addition, the power supply and control instrumentation shall use commonly accepted U.S. standard electrical services.

3.4.2 Instrumentation. All required instrumentation (i.e., liquid helium level sensors, pressure transducers, temperature sensors, current meters, etc.) in the quantity and locations required to safely and efficiently run the magnet shall be included in the design and construction of the magnet system. The instrumentation shall include, but not be limited to, the following devices:

LHe and LN2 (if LN2 used) liquid level indicators
LHe temperature indicators

3.4.3 Control Panel. There shall be one remotely located, main control panel for operating the magnet. This will be the point for display of alarm and warning conditions, turning the magnet on and off, ramping the magnet to selected target fields, etc. Elements of the control system shall be off-the-shelf and easily available for replacement. Cables for connecting the control panel to the magnet shall be 6 meters (20 feet) in length.

3.4.4 Computer Interface. Parameters relevant to the operation and use of the magnet (i.e., current, temperatures, levels, alarms) shall be available for interface and remote monitoring through a standard IEEE bus accessible to the experiment data acquisition system.

3.4.5 Set Point and Drift. The magnet shall be capable of being manually set at any field from zero to the system maximum to within 1% of the setting. The magnetic field shall not drift from its set point by more than 10 ppm per hour.

3.4.6 Field Ramp Time. The ramping time for the magnet to switch from a de-energized state to nominal design running current in a stable running configuration shall be less than 30 minutes.

3.4.7 Crash Button. The magnet system will be supplied with a crash button to safely shut down the magnet in the shortest possible time. It is expected that this crash mechanism will cause the magnet to quench.

4.0 Quality Assurance

4.1 Articles furnished in compliance with this specification shall be produced under the controls established herein and as required by the applicable contract. BNL-QA-101, BNL Supplier Quality Assurance Requirements, is included as part of this specification. The QA requirements shall be in accordance with Sections 3, 3.1.3, 4.1, 4.2, 4.6, 4.10, 4.10.1-4, 4.13, 4.16, 4.19, 4.20, 4.23, 4.28, 4.31, 4.34, and 4.40.

4.2 The Seller shall maintain a quality assurance system that ensures quality workmanship and conformance to the requirements of the specification from start of design through final production.

4.3 Calibration System. The Seller shall have a calibration and maintenance system to control the accuracy of the measurements and test equipment used to meet the requirements of this specification. As a minimum the system shall include prescribed calibration intervals, source of calibration, and monitoring system used to ensure adherence to the calibration schedule. Measurement and test equipment used to meet the purchase order requirements shall be calibrated against certified standards that are traceable to national standards such as the National Institute of Standards and Technology (NIST). Documentation in support of this requirement shall be readily available to BNL.

4.4 Underwriter Certification. The system shall use electronic components that are certified by a nationally recognized testing laboratory (NRTL). Where uncertified components must be used, the Seller shall determine the equipment to be safe for its intended use per paragraph 4.40 of BNL-QA-101. The Seller shall notify Buyer of components that are without certification. Electrical schematics and/or test data for these components shall be made available to BNL by the Seller for review.

5.0 EBIS Facility.

5.1 Utilities. The following utilities are available at the installation site:

a) Electric power:
   i) 480 VAC, 60 Hz, 3-phase, 3-wire
   ii) 208 VAC, 60 Hz, 3-phase, 5-wire
   iii) 120 VAC, 60 Hz, 1-phase

   The system shall be earth grounded for safety purposes.

b) Cooling water.

c) Compressed air.

d) Liquid nitrogen supply.

e) Liquid helium supply.

6.0 Marking

6.1 The side of the magnet shall be marked, either by painting or affixing a data plate, with the following information in 25 mm or greater height lettering:

EBIS Superconducting Solenoid
Vendor's name
Maximum Field = ? @ ? Amps
Weight

6.2 Nameplate. The magnet shall have a permanently attached nameplate that bears the maximum allowable pressures and volumes for the vacuum and cryogenic vessels, date of manufacture, and drawing number.

Appendix A – Acceptable and Unacceptable Field Plots for EBIS Magnet System

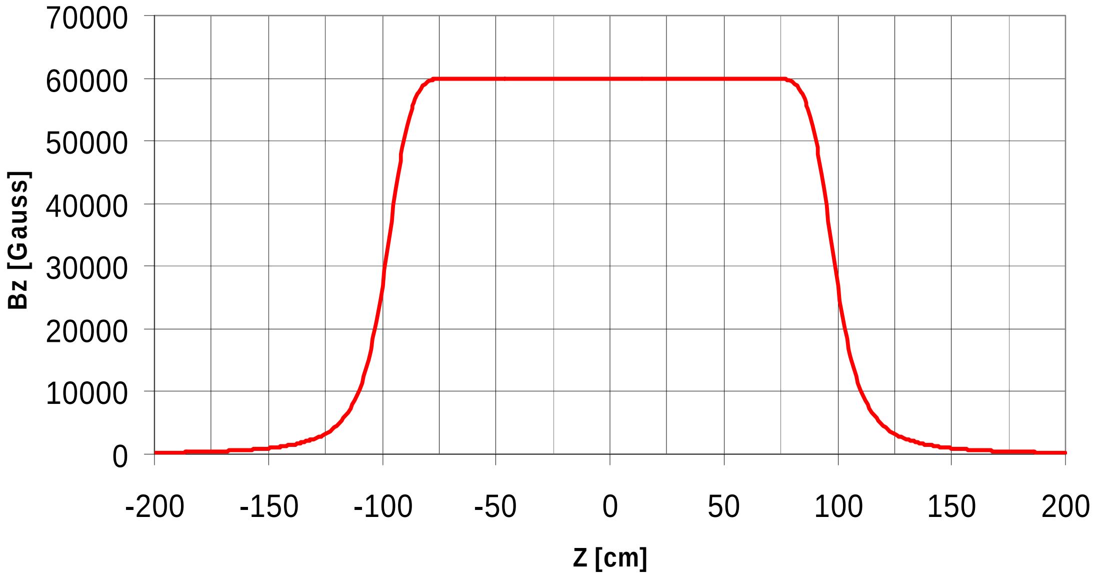
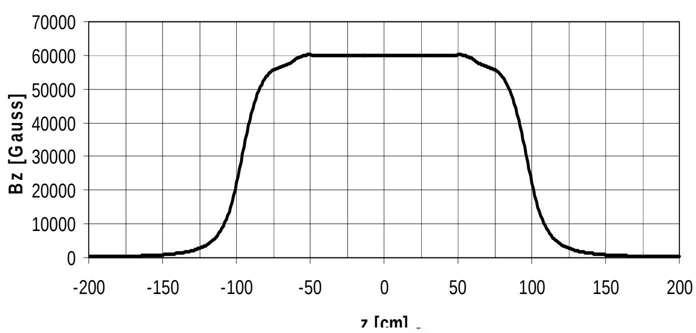
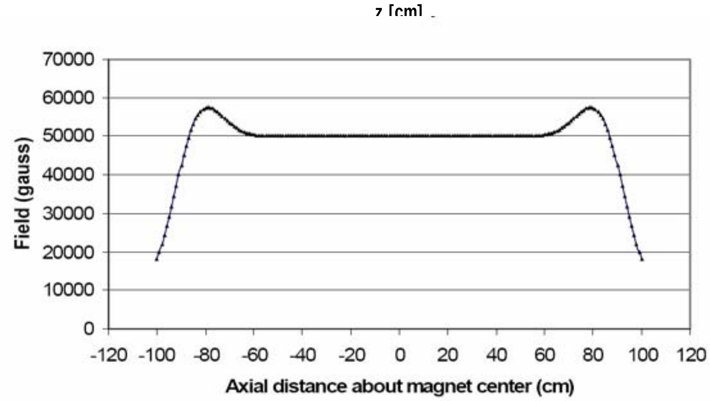


Figure 1: Acceptable Field Plot (Typical)



Figures 2: Unacceptable Field Plot



Figures 3: Unacceptable Field Plot

Appendix A